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GPO PRICE $ ______________

CFSTI PRICE(S) $ ______________

Hard copy (HC) 2.00

Microfiche (MF) .50

ff 653 July 65

FACILITY FORM 602

N67 12903 (ACCESSION NUMBER)	(THRU)
28 (PAGES)	1 (CODE)
CR-80200 (NASA CR OR TMX OR AD NUMBER)	03 (CATEGORY)

THERMO ELECTRON

ENGINEERING CORPORATION

Contract No. 951263

Report No. TE 91-66

SECOND QUARTERLY REPORT
SOLAR THERMIONIC
GENERATOR DEVELOPMENT

June 1966

Prepared for

Jet Propulsion Laboratory
Pasadena, California

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

Thermo Electron Engineering Corporation, 85 First Avenue, Waltham, Massachusetts 02154

INTRODUCTION

This document constitutes the Second Quarterly Report of the work being performed under Thermo Electron's Contract No. 951L63 with the Jet Propulsion Laboratory.

The objectives of this program are twofold, and are to be reached under two task efforts; they are:

I. To develop a converter of the design used under Task II of Contract No. 950671, which is capable of delivering a power output of 20 watts/cm^2 at one volt, with a minimum measured efficiency of 16%.

II. To develop a prototype structure of a 14% efficient multi-converter generator capable of operation in cislunar space with a concentrator 9. 5 ft. in diameter and which uses the converters developed under Task I.

Task I centers on the iterative construction of 9 engineering models of a solar energy thermionic converter. The aim of the first model is to partially duplicate the best converter developed under Task II of Contract No. 950671. The second and third are principally geared to the incorporation of a modification in the heat transfer path of the collector-radiator structure to assure efficient and reliable heat transfer. The fourth and fifth are intended to effect a change in the materials of the convoluted emitter structure whereby the entire structure will be made of rhenium. The sixth and seventh converters will study two new collector materials and the eighth will be a final prototype incorporating all the features found to improve performance in the course of the work. The ninth prototype will duplicate the eighth except that the interelectrode spacing will be increased to 2 mils in order to make a performance comparison. It is possible that this step will be accomplished before the fabrication of the ninth prototype.

Task II involves a generator flux analysis, a shielding evaluation, and a mock-up environmental test based on the design of a selected generator design. The analysis will determine the best number of converters to match the converter heat requirements to the available solar energy, the optimum cavity aperture size, the required adjustments of surface emissivity and absorptivity values to insure even flux distribution, and the effects of changes in emitter temperature and heat input on flux distribution within the generator. The shielding test is primarily intended to verify design assumptions on shielding heat losses, and to select a preferred shield configuration. The mock-up environmental tests will be conducted to explore all areas of possible structural weakness to vibration, shock, acceleration and acoustical environments, and effect the design changes indicated.

This report covers progress for the period March 1, 1966, to June 1, 1966.

SUMMARY

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During the second quarter, the second engineering model, T-202, has been tested, and two unsuccessful attempts at the fabrication of the third, T-203, have been made. Test results on T-202 have indicated that the interelectrode spacing of converter T-202 is less uniform than that of converter T-201 and has a larger average value. Consequently, the performance of converter T-202 has been lower in the unignited mode, and higher in the ignited mode than the performance of converter T-201. The attempts to fabricate T-203 failed because a more stringent revised outgassing procedure was applied in which the collector temperature during outgassing was brought up to 800°C rather than 700°C. The higher temperature appears to have caused the failure of the same braze in both instances. A new attempt is now in progress to fabricate T-203, efforts will be made to control the quality of the critical braze more carefully, and the collector temperature during outgassing will be kept at 700°C.

The work on Task II has been pursued as far as the statement of work allows, and all the work done has been presented in the First Quarterly Report. Continuance of work on this task is contingent on the availability of a converter model with a sufficiently high level of performance to permit calculation of generator electrical performance, and to conduct meaningful converter shielding experiments.

Cutlis

1.1 Performance of Converter T-202

Converter T-202 has been tested according to JPL Engineering Note ADEN 342-005. This procedure consists of first making a relative collector work function measurement and sampling two I-V traces, then running under steady-state at a substantial output current for approximately 150 hours, making a new collector work function measurement, proceeding to evaluate the other converter characteristics by I-V curve and cesium conduction measurements, and finally testing the converter under steady state conditions.

Figure 1 gives the I-V characteristics obtained from converter T-202. The dashed lines represent the envelopes of dynamic measurements made at true emitter temperatures as indicated with optimized collector temperatures, and the solid lines give the steady-state outputs obtained at the true hohlraum temperatures indicated, with the collector allowed to reach its own equilibrium temperature, unaided by the electrical heater provided for collector temperature optimization. As may be seen, the spacing between the branches corresponding to ignited operation is not uniform; it is narrower between 1900 and 2000° K than it is between 1800 and 1900° K. This is because it had been initially assumed that optimum collector temperatures would be obtained at 1.75 times the reservoir temperature and the 2000° K curves were run making this assumption. Further testing showed that a ratio of 1.60 gives a nearer to optimum condition and this ratio was adopted for the 1900° K and 1800° K runs, and will continue to be used in all further converter testing.

Of particular interest in Figure 1 is the point obtained in steady state, with no collector heat applied, at 1800° C and 0.8 volt output. The collector temperature achieved there is 1073° K at an output current of 52.3 amperes. This compares favorably with the desired goal of 1015° K at 50.0 amperes, 1700°C, and it appears that, for the moment, no further attempts at adjusting radiator size should be made.

Figure 2 compares the T-202 performance with that of converter T-201, and also gives T-103 results previously obtained. The figure reveals that, in the ignited mode, the performance of T-201 and T-202 is similar except that in steady-state, T-201 was not able to reach a sufficiently high collector temperature to attain the performance level predicted by the dynamic curve. In the unignited mode, the performance of T-201 is superior to that of T-202, and this result would indicate that the interelectrode spacing of T-202 is larger than that of T-201. This would not be surprising for T-202 was noticed to have a collector face convex by .0004" in addition to a convex emitter. This departure from flatness in the face of the collector of T-202 is the result of a 15-minute chemical etch on the face. Converter T-201 had a ground collector which was therefore flat within .0001".

Figure 3 gives the cesium conduction data obtained with T-201 and T-202, and tends to verify that T-202 must have had a larger average interelectrode spacing.

As a result of these findings, it was recommended to JPL that the etching time for the collector of converter T-203 be reduced to 5 minutes, and that the T-202 collector radiator geometry be preserved. Furthermore, it was recommended to reduce the side-emission area to 1 cm^2 from the 2 cm^2 used previously for T-201 and T-202. This area had had a value of 1.3 cm^2 in T-103 and 0.5 cm^2 in all other T-100 converters. It was increased in T-201 and T-202 to 2 cm^2 to enhance output contribution to the lateral area of the collector. Since there is a large discrepancy in the output of converters T-202 and T-103 in the extinguished mode, it is felt that some effort at exploring the influence of lateral collector area should be made.

Further interesting remarks on the test results of converter T-202 can be made from the data sheets. A comparison of the I-V traces Nos. 1 and 2 with Nos. 24 and 25 reveals some shift in the relative collector work function data. The I-V traces are taken at a reservoir temperature of 680° K, corresponding to a cesium pressure of 20 mm Hg, and therefore a pd of 20 mil-torrs at a spacing of 1 mil. It is known that, in the ignited region, the voltage drop in the interelectrode plasma required for ignition is correlated by the value of pd, and that it is nearly constant for pd values in the range from 20 to 30 mil-torrs. The value of the voltage drop is then about 0.49 volts, and the data scatter for 84 per cent of 312 points is ±10% (Figure 49, Task II Final Report, JPL Contract No. 950671). In the absence of back-emission from the collector, the electrode output voltage of the converter in the ignited mode should therefore be:

$$V_o' = \phi_E - \phi_C - 0.49$$

with some variation expected as a function of output current because of plasma resistivity. At an emitter temperature of 2000° K, and a reservoir temperature of 680° K, the value of T_E/T_R is 2.94, and the Rasor plot for Te shows that the corresponding emitter work function will be 2.44 ev. as shown in Figure 4. Thus, the electrode output voltage in the ignited mode with negligible back emission from the collector should be

$$V_o' = 1.95 - \phi_C \; .$$

Since for the T-200 converter, the emitter lead resistivity equals that of the T-100 series which is .0014 ohms (not including the resistance of the stud on which the emitter lead is attached), the observed output voltage should be correlated by

$$V_o = 1.95 - \phi_C - .0014 \; I_o \; .$$

At 40 amperes, this expression reduces to

$$\phi_C = 1.89 - V_{40}$$

Shifting our attention at the I-V trace No. 2 of converter T-202, we find an observed voltage at 40 amperes of 0.70 volts, implying a collector work function of 1.19 ev.* This value is of course unrealistic, it would normally approach 1.5 ev, and it is because of this inconsistency that this measure of collector work function is considered to be relative. In other words, the value of a trace such as I-V No. 2 lies in its ability to reveal shifts in position rather than accurate values of work function. For instance, I-V traces Nos. 24 and 25 show values of V_{40} of 0.63 and 0.69 volts which amount to a shift of approximately 0.04 ev in work function. Such a small shift could be due to a change in emitter work function, although experience indicates that emitter work functions tend to be more stable than collector work functions except in those instances where the emitter bond fails.

The T-202 collector work function I-V traces compare well with those obtained for T-201. In that converter the final values of V_{40} had been 0.70 and 0.71 volts for the same conditions.

To evaluate the design of the cesium reservoir of converter T-202, an additional test was performed, and the data are presented in sheet 7 of the data which are also plotted in Figure 5. These data show the equilibrium reservoir temperatures achieved as a function of reservoir heater current, for a collector temperature of 854° K. As it may be seen, the reservoir has a tendency to overheat (when not connected to a water-cooled strap) even at

---

*To check the requirement of small collector back emission, we note that, at the emitter temperature of 961° K corresponding to I-V trace No. 2, the back emission for a collector work function of 1.5 ev would be 3.8 amperes, compared with a forward emission of 40 amperes.

the relatively low collector temperature of 854° K. A desirable equilibrium reservoir temperature would be approximately 623° K for optimum output at 50 amperes. Further effort on improving the cesium reservoir design will be made in subsequent T-200 models.

1.2 Fabrication of Converters T-203 and T-203A

The fabrication of both converters, T-203 and T-203A, could not be completed successfully. These converters were fabricated following the same procedures described in the First Quarterly Report, except for a change in the outgassing specifications. Prior to T-203, the converters were outgassed with a collector temperature generally in the vicinity of 700° C. Although the performance characteristics had not revealed a need for a higher collector outgassing temperature, it was felt that it should be increased to 800° C because during testing the collector temperature will often reach that level. Consequently, both T-203 and T-203A were outgassed maintaining the collector temperature at 800° C for a period of 64 hours for T-203, and 24 hours for T-203A. At the end of outgassing, converter T-203 showed immediate signs of having developed a leak; when air was released in the external vacuum system, the exhaust vac-ion pumping system connected to the vacuum envelope of the converter showed a rapid rise in pressure. Subsequent leak checking indicated that the failure had occurred either at the palladium braze between the niobium seal flange and the collector stem, or at the ceramic seal. Since no such failure had been encountered before, it was assumed that its nature may have been accidental, but the experience with converter T-203A was to show later that the failure is consistent with the rise in collector outgassing temperature, and that it occurs at the palladium braze.

Converter T-203A did not show the signs of difficulty at the end of outgassing as did T-203. It was therefore charged with cesium and instrumented for test. In test it developed no output, and it was decided to open the reservoir, connect a new tubulation and leak check it. Again the leak was found in the general area of the seal, but this time it was felt important to pinpoint its location. The converter was therefore sectioned so that the seal area could be exposed without damaging it. A new tubulation was brazed to facilitate connection to the leak detector, and the leak was found to be at the palladium braze. The emitter structure was then cut out to allow direct visual and mechanical inspection of the braze. This examination revealed that at some places the bond to the molybdenum had occurred over areas only 0.020" wide which were easily broken by the application of relatively low forces. The fracture observed was along intergranular surfaces in the molybdenum material adjacent to the braze.

The emitter of converter T-203A was obtained from a new pressure bonded assembly etched for 1 minute and thermally stabilized for 1 hour at 2100°C. The etching time was reduced to preserve flatness, and the firing time corresponded to the optimum procedure found in the treatment of the previous three emitters for converters T-201, 202 and 203. After firing, the flatness check showed that the emitter was convex at the center by .0003" which is the minimum value that it has been possible to achieve. This emitter has now been salvaged for the fabrication of converter T-203B. Converter T-203B is being fabricated using a collector subassembly with a palladium braze which had good flow, and therefore does not appear to have any narrow areas of bonding.

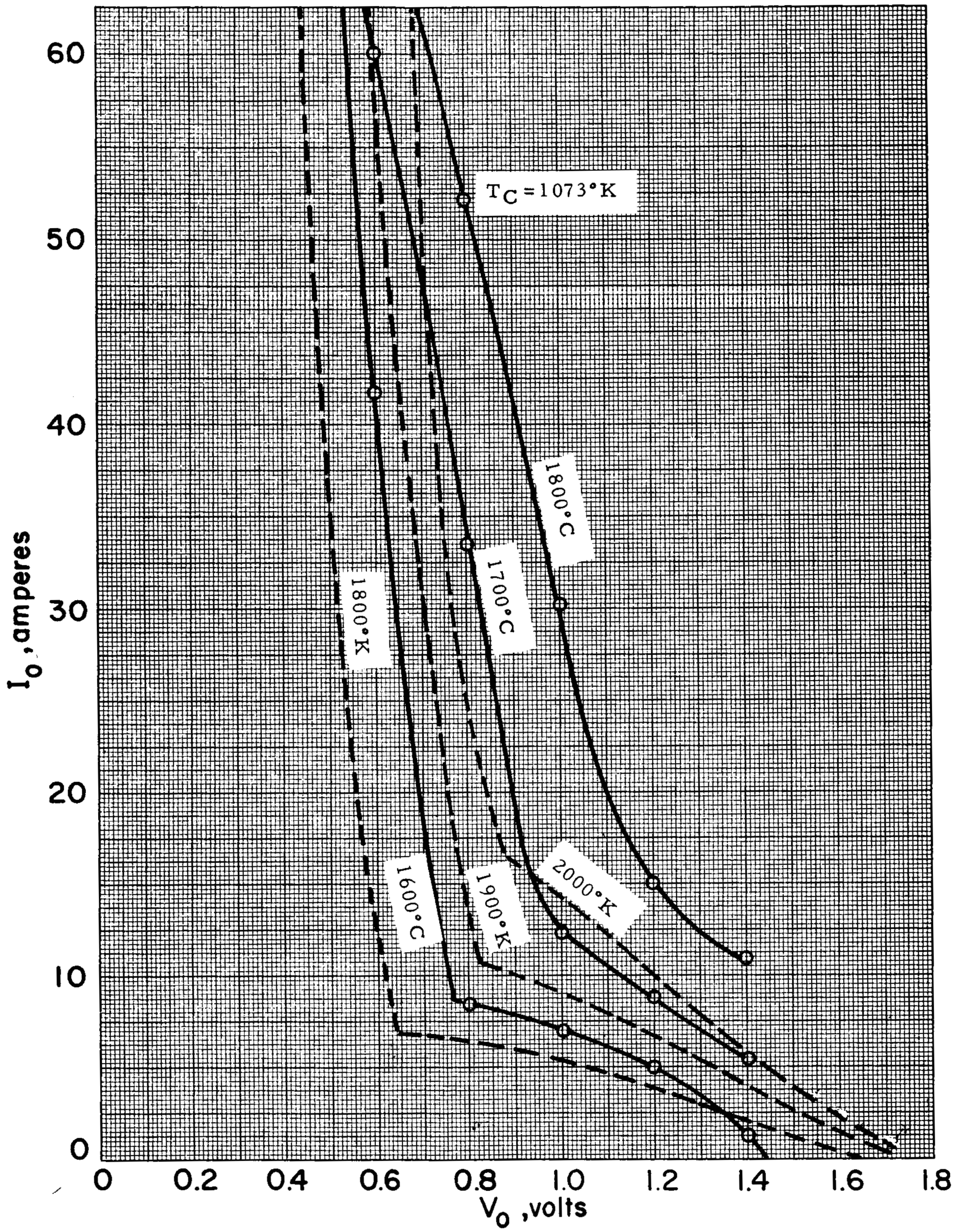

Figure 1. T-202 I-V Characteristics

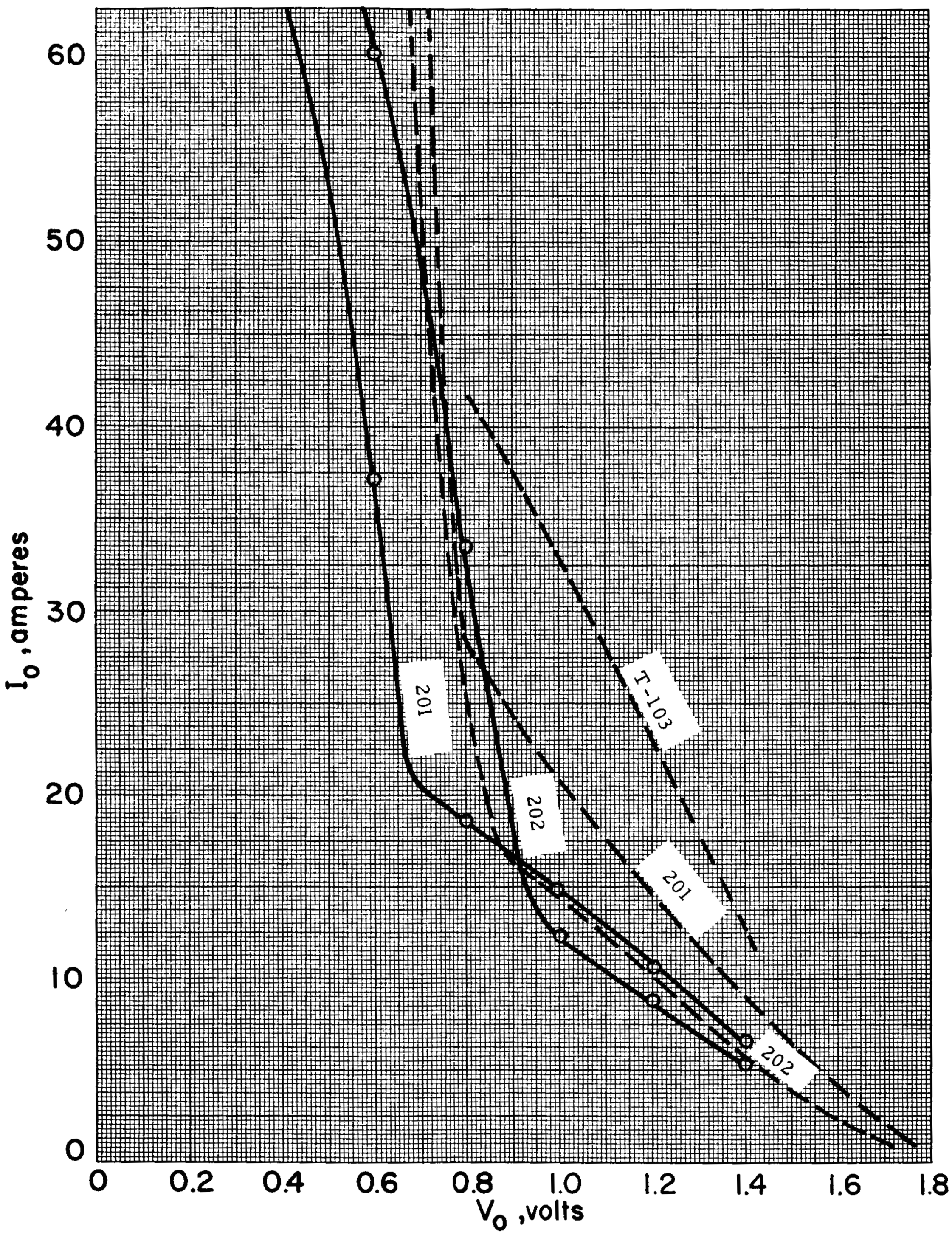

Figure 2. Comparison of T-201 and T-202 I-V Characteristics at 1700°C and 2000°K (------).

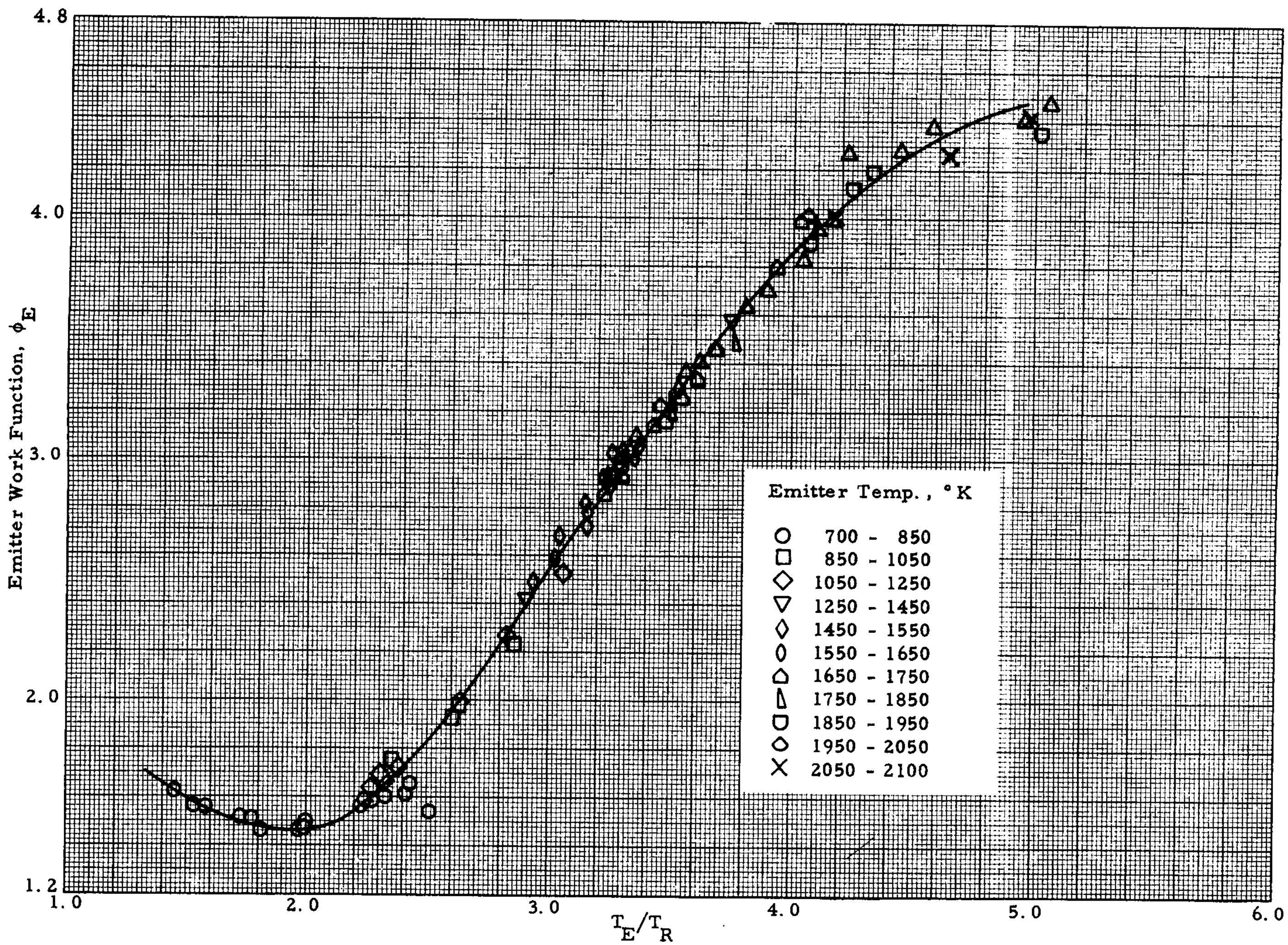

Figure 4. Correlation of the Experimental Emitter Work Function Against T_E/T_R

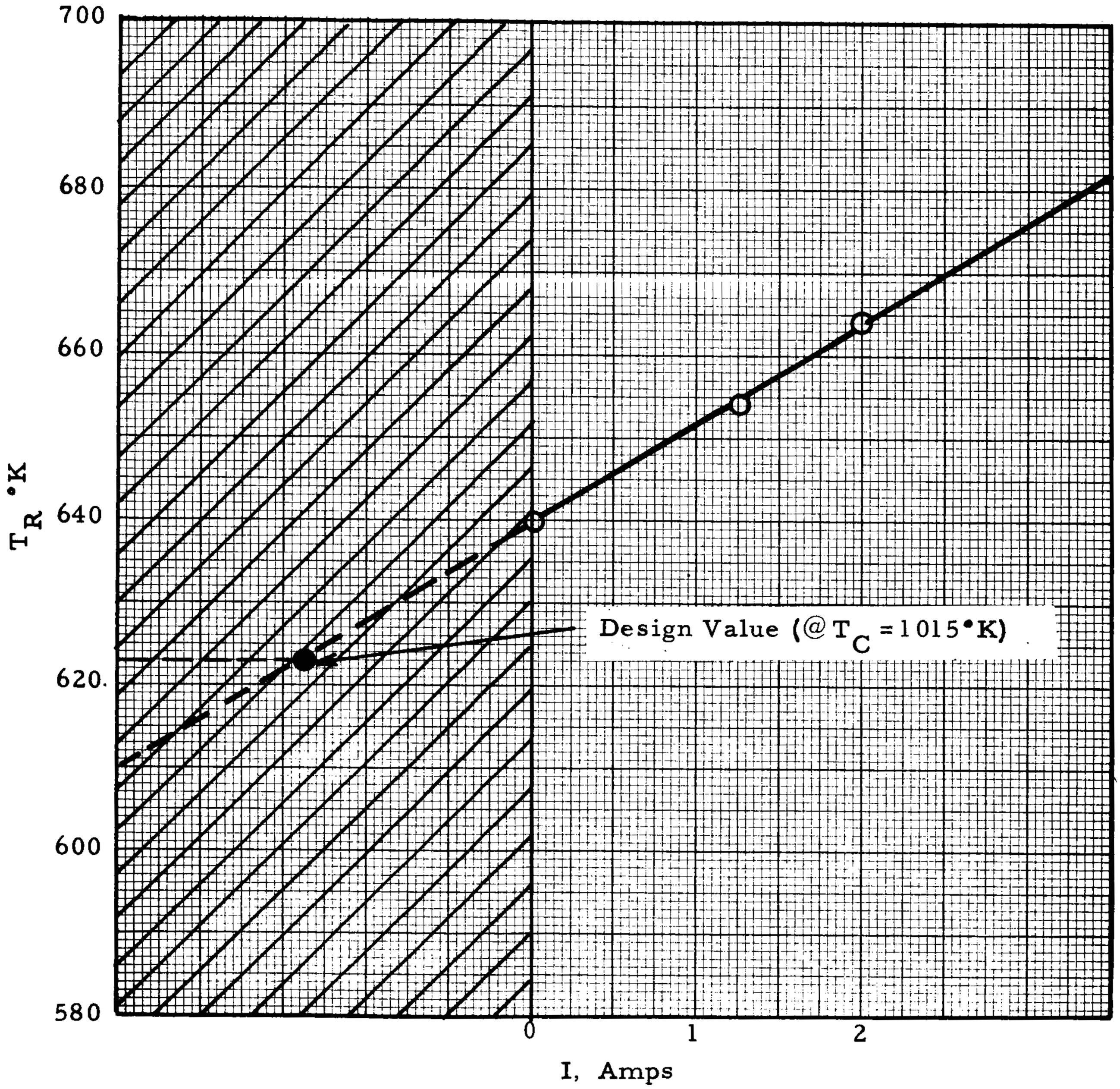

Figure 5. Thermal Characteristics of T-202 Reservoir (T_C = 854°K)

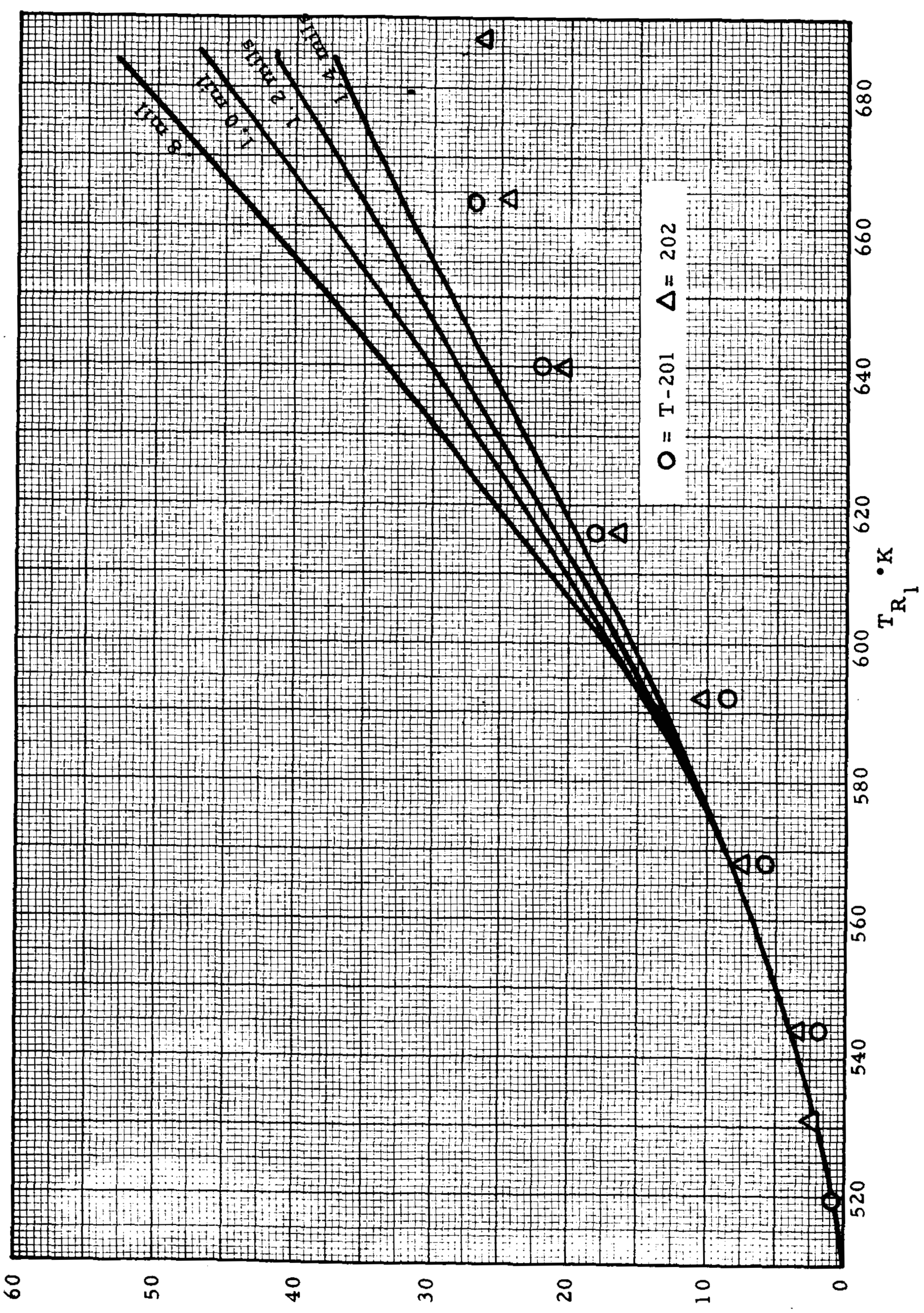

Figure 3. Cesium Conduction

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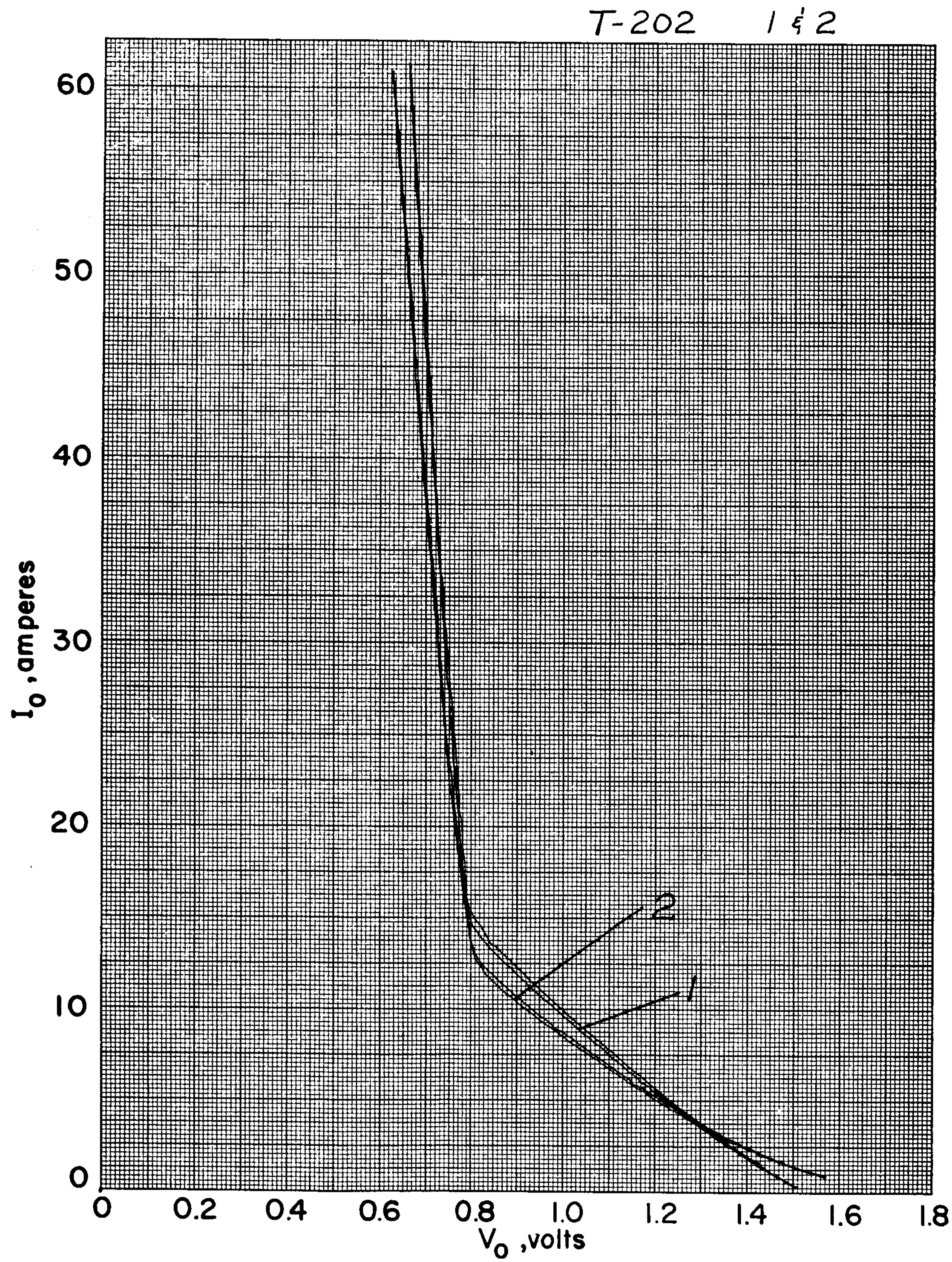

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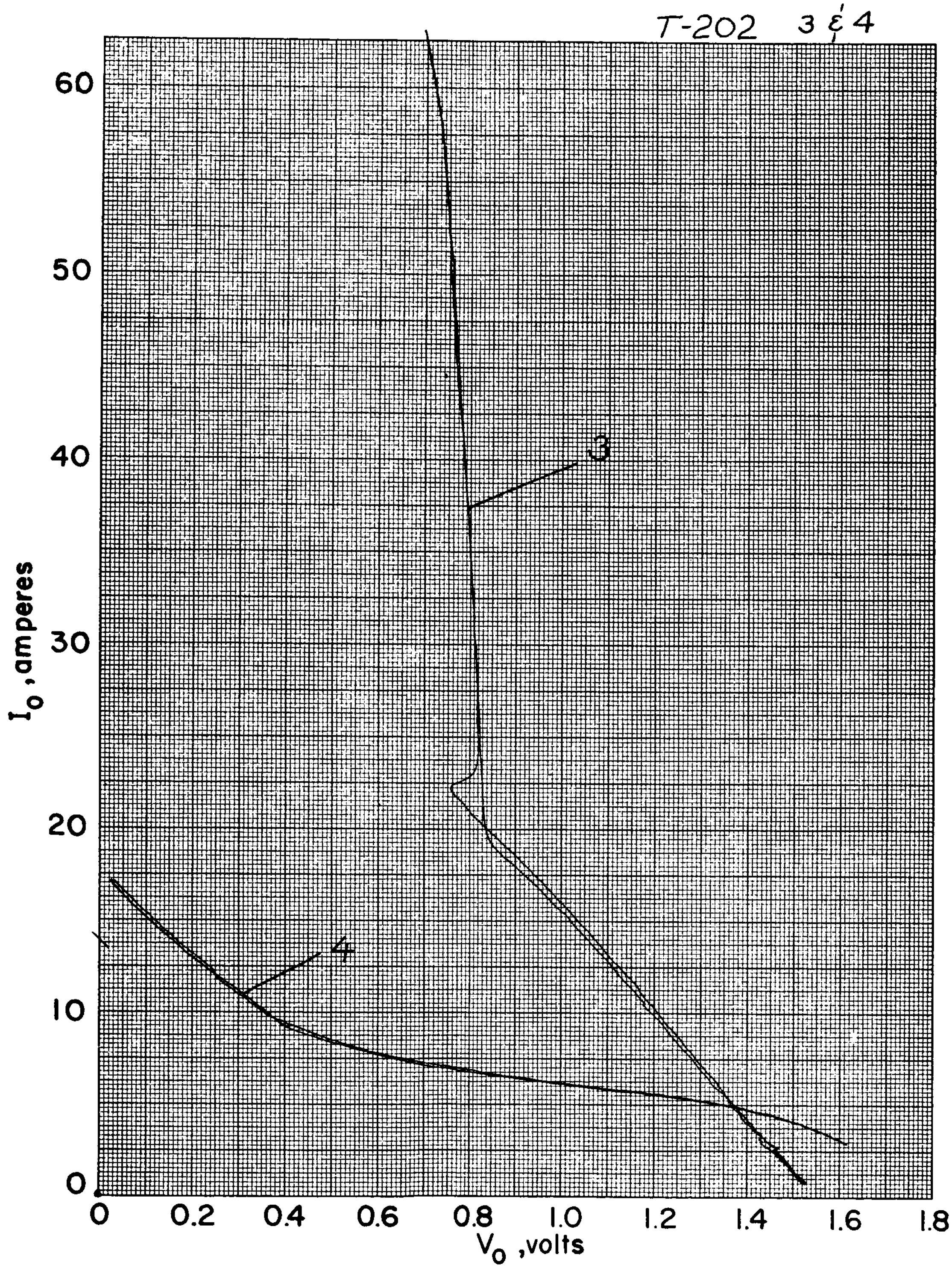
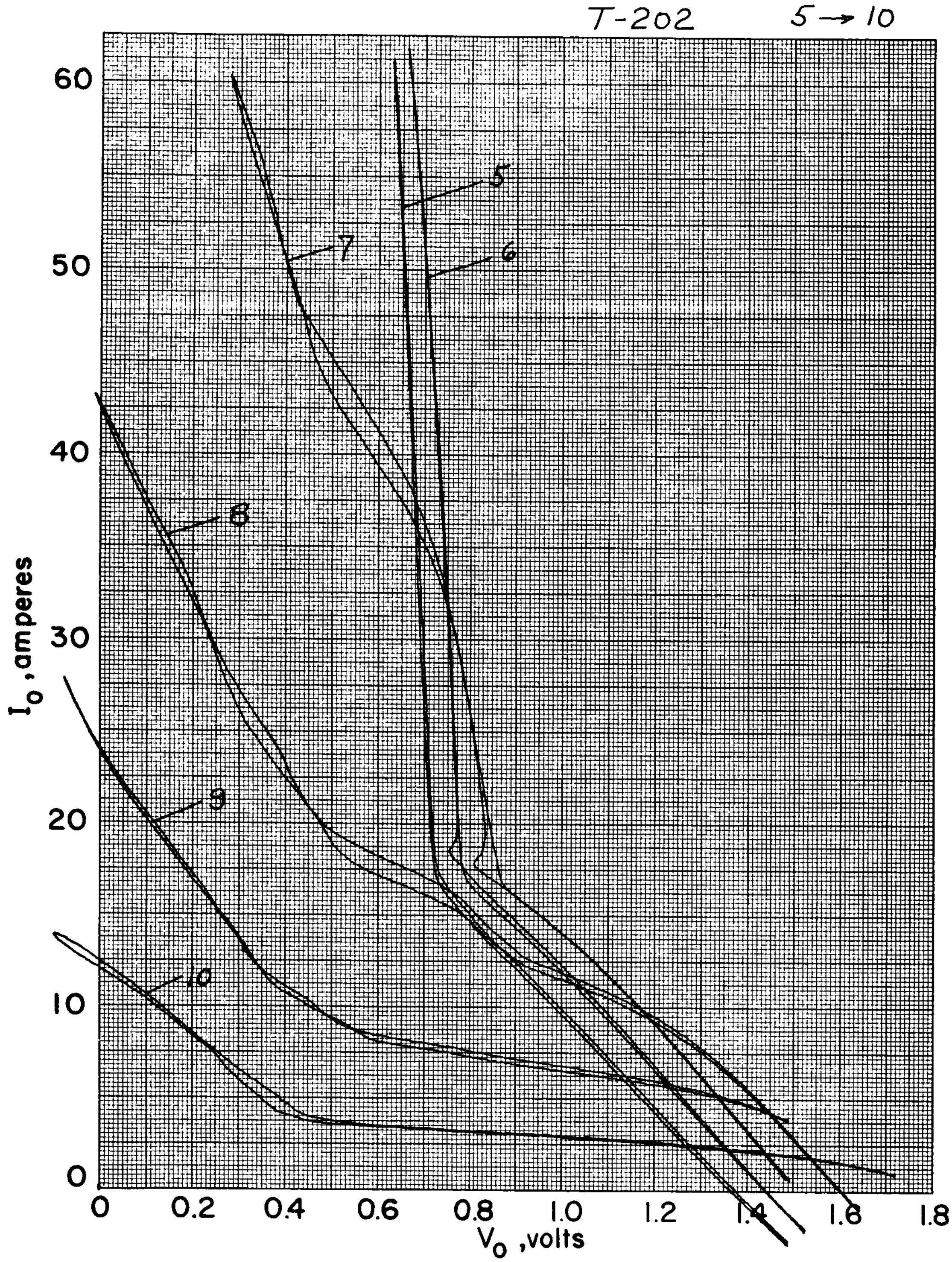
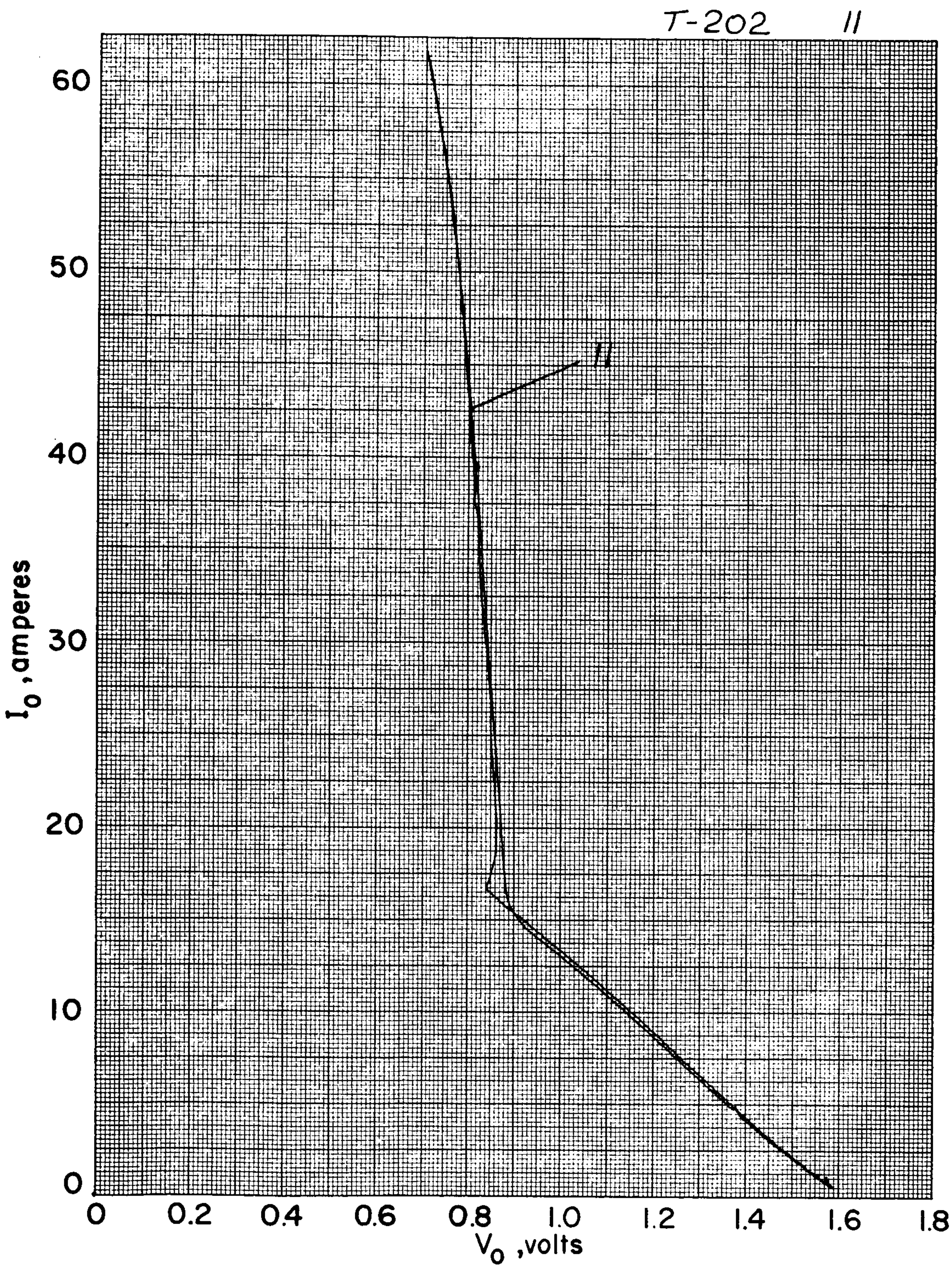
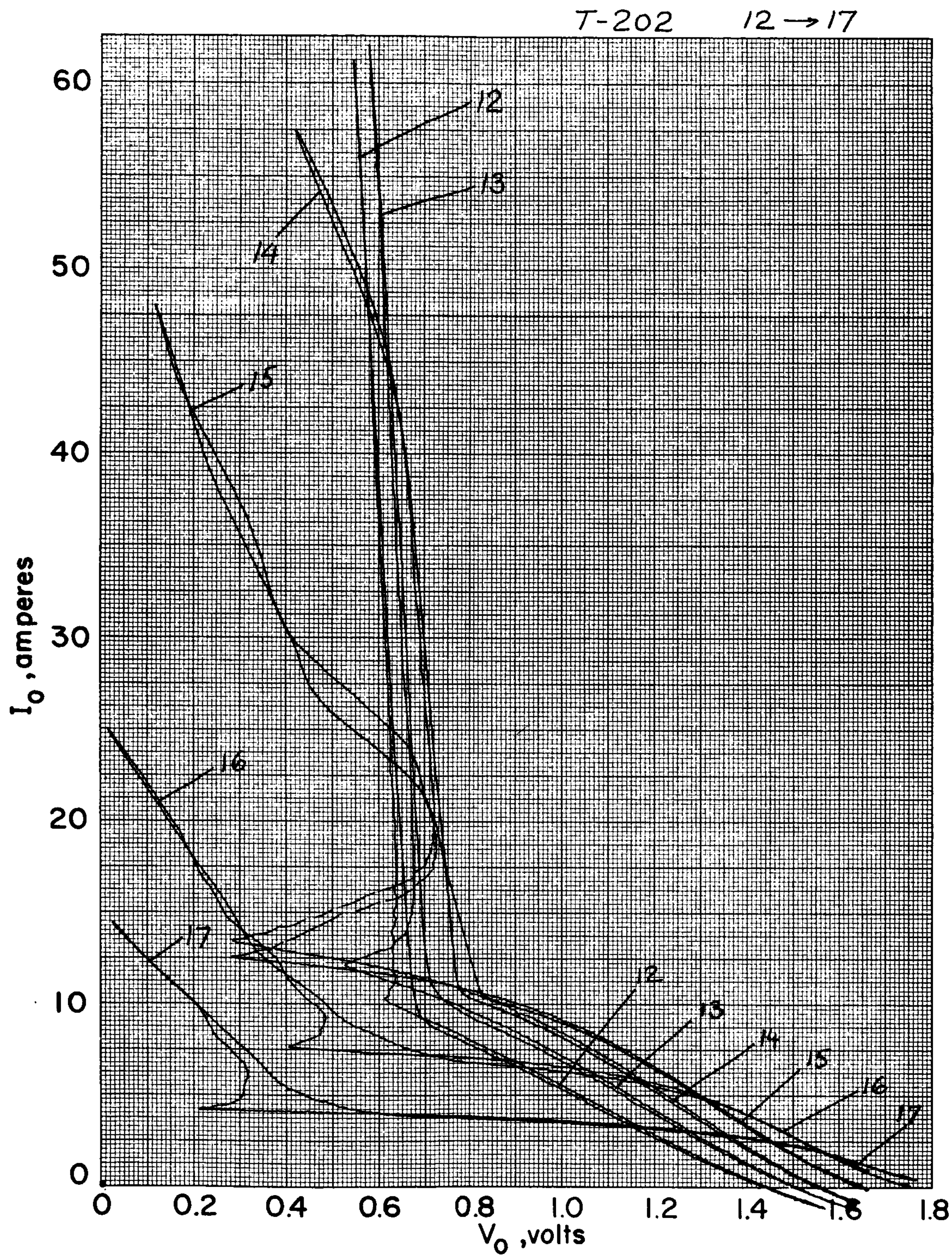
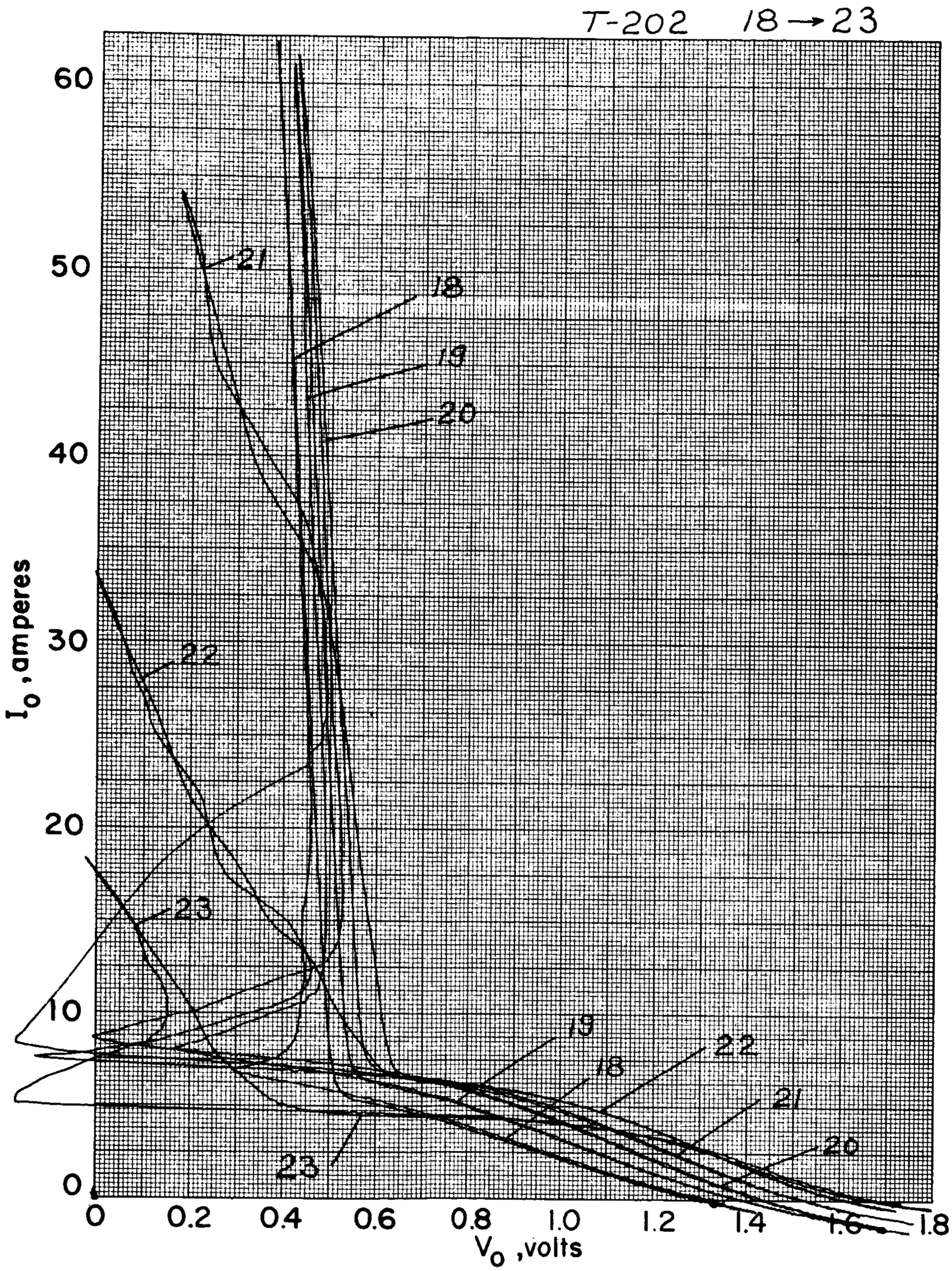



T-202
5 → 10
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
I_o, amperes
V_o, volts
5
6
7
8
9
10


T-202 11
11
60
50
40
30
20
10
0
I_0, amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_0, volts


T-202 12 → 17
I_0, amperes
V_0, volts
0
10
20
30
40
50
60
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
12
13
14
15
16
17

7327


T-202 18→23
60
50
40
30
20
10
0
I_o, amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts
21
18
19
20
22
23
19
18
22
21
20
23

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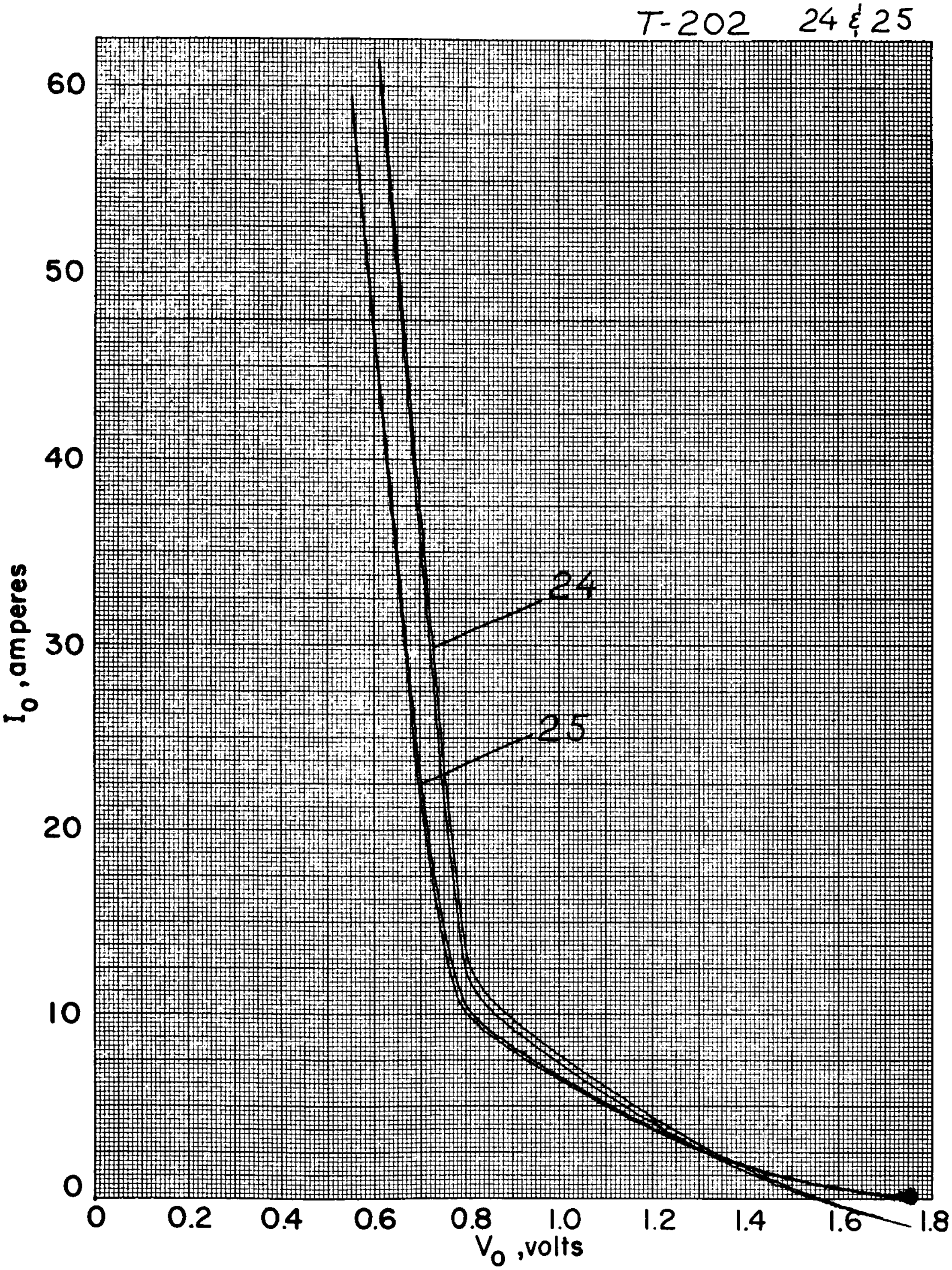

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Sheet 1 of 7

Converter No. T-202 Des. II Run No. 1 c̄ 2 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-11-66	—	—	—	—	—	—	3-14-66	—	3-15-66
Time		1050	1110	1350	1430	1540	1610	1640	1120	1250	0900
Elapsed Time, Hours		—	—	—	—	—	—	—	0	1.5	21.6
T_O, °C		1708	1708	1708	1703	1714	1711	1704	1710	1713	1708
T_O Corrected, °C		1718	1718	1718	1713	1724	1721	1714	1720	1723	1718
$\Delta T_{Bell\ Jar}$, °C		18	18	18	18	18	18	18	18	18	18
T_H, °C		1736	1736	1736	1731	1742	1739	1732	1738	1741	1736
ΔT_E, °C		8	8	8	7	15	12	8	12	12	12
T_E, °K		2001	2001	2001	1997	2000	2000	1997	1999	2002	1997
V_o, volts		—	—	—	—	.60	.80	1.00	.80	.80	.80
I_o, amps		23 av.	23 av	28 av	13 av	63.7	40.0	17.9	41.1	40.7	42.0
P_o, watts		—	—	—	—	38.2	32.0	17.9	32.9	32.6	33.6
I-V Trace No.		1	2	3	4	—	—	—	—	—	—
T_R	mv	16.7	16.7	14.3	11.8	15.4	14.0	13.2	14.4	14.4	14.3
	°C	407	407	350	290	376	343	324	353	353	350
	°K	680	680	623	563	649	616	597	626	626	623
T_C	mv	2-538	2-376	2-532	2-332	2-682	2-460	2-225	2-466	2-466	2-466
	°C	769	688	766	666	841	730	613	733	733	733
	°K	1042	961	1039	939	1114	1003	886	1006	1006	1006
T_C base inner	mv	27.2	23.7	26.8	24.2	27.5	24.7	21.6	25.0	24.9	24.9
	°C	654	572	644	583	661	595	522	602	600	600
T_C base outer	mv	27.0	23.2	26.5	24.3	27.0	24.2	21.2	24.5	24.4	24.4
	°C	649	560	637	586	649	583	513	590	588	588
$T_{Radiator}$	mv	23.2	20.7	22.9	21.1	23.2	21.3	19.1	21.6	21.5	21.5
	°C	560	501	553	511	560	516	464	522	520	520
V_{eb}, volts		988	988	988	997	977	984	993	980	979	981
I_{eb}, mA		260	258	260	189	364	299	230	302	302	303
$E_{Filament}$, volts		4.9	4.9	4.8	4.6	5.2	5	4.8	5	5	5
$I_{Filament}$, amps		21	21	21	20	23	21.5	21	21.5	21.5	21.5
$I_{Coll. Heater}$, amps		9	0	9	9	0	0	0	0	0	0
$I_{Res. Heater}$, amps		~2	~4	~2	~1	~4	~3	~3	~3	~3	~3
Vacuum, 10^{-6} mm Hg		6.6	6.4	5	4.6	4.4	4.2	4.2	4.0	3.8	3.4
Measured Efficiency, %											

NOTES:

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Converter No. T-202 Des. II Run No. 2 & 3 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-15-66	3-16-66	3-17-66	3-21-66	3-21-66	—	—	—	—	—
Time		1710	1050	1145	0915	1448	1502	1518	1530	1543	1557
Elapsed Time, Hours		29.8	47.5	72.4	165.9	—	—	—	—	—	—
T_O, °C		1707	1708	1696	1702	1712	1710	1710	1710	1710	1708
T_O Corrected, °C		1717	1718	1706	1712	1722	1720	1720	1720	1720	1718
$\Delta T_{Bell\ Jar}$, °C		18	18	18	18	13	13	13	13	13	13
T_H, °C		1735	1736	1724	1730	1735	1733	1733	1733	1733	1731
ΔT_E, °C		12	12	12	12	9	9	10	8	7	6
T_E, °K		1996	1997	1985	1991	1999	1997	1996	1998	1999	1998
V_O, volts		.80	.80	.80	.80	—	—	—	—	—	—
I_O, amps		42.2	43.4	43.3	42.7	24av	25av	28	18	13	6
P_O, watts		33.8	34.7	34.7	34.2	—	—	—	—	—	—
I-V Trace No.		—	—	—	—	5	6	7	8	9	10
T_R	mv	14.2	14.2	14.3	14.2	15.2	14.3	13.4	12.6	11.8	11.0
	°C	348	348	350	348	372	350	329	309	290	271
	°K	621	621	623	621	645	623	602	582	563	544
T_C	mv	2-466	2-466	2-466	2-466	2-712	2-634	2-558	2-494	2-424	2-356
	°C	733	733	733	733	856	817	779	747	712	678
	°K	1006	1006	1006	1006	1129	1090	1052	1020	985	951
T_C base inner	mv	24.8	24.9	24.8	24.9	30.8	29.3	27.5	26.9	26.0	23.6
	°C	597	600	597	600	740	704	661	647	626	569
T_C base outer	mv	24.3	24.4	24.3	24.4	30.7	29.3	27.4	26.7	26.0	23.3
	°C	586	588	586	588	737	704	659	642	626	562
$T_{Radiator}$	mv	21.4	21.5	21.4	21.5	25.5	24.6	23.5	23.0	22.5	21.0
	°C	518	520	518	520	614	593	567	555	543	508
V_{eb}, volts		982	981	983	980	988	988	988	993	994	998
I_{eb}, mA		302	303	301	302	251	250	249	212	200	178
$E_{Filament}$, volts		5	5	5	5	4.9	4.9	4.9	4.8	4.7	4.6
$I_{Filament}$, amps		21.5	21.5	21.5	20.5	20	20	20	19.5	19	19
$I_{Coll.\ Heater}$, amps		0	0	0	0	14	12	11	11	12	0*
$I_{Res.\ Heater}$, amps		~3	~3	~3	~3	~2	~2	~20	~2	~0	~0
Vacuum, 10^{-6} mm Hg		3.3	3.2	3.0	2.7	5.2	5.0	4.8	4.7	4.6	4.6
Measured Efficiency, %											

NOTES: * Collector heater failed during data point 10
Bell jar calibrated at end of

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Sheet 3 of 7

Converter No. T-202 Des. II Run No. 3 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-22-66	—	3-23-66	—	—	—	—	—	—	—
Time		1540	1552	1257	1307	1317	1327	1337	1347	1440	1450
Elapsed Time, Hours		—	—	—	—	—	—	—	—	—	—
T_O, °C		1712	1710	1615	1615	1614	1613	1612	1612	1518	1518
T_O Corrected, °C		1722	1720	1624	1624	1623	1622	1621	1621	1526	1526
$\Delta T_{Bell\ Jar}$, °C		13	13	11	11	11	11	11	11	9	9
T_H, °C		1735	1733	1635	1635	1634	1633	1632	1632	1535	1535
ΔT_E, °C		11	9	9	9	9	8	7	6	9	9
T_E, °K		1997	1997	1899	1899	1898	1898	1898	1899	1799	1799
V_O, volts		.829	—	—	—		—				—
I_O, amps		39.7	27	23	24	23	20	10	6	22	22
P_O, watts		32.9	—	—	—	—	—	—		—	—
I-V Trace No.		—	11	12	13	14	15	16	17	18	19
T_R	mv	14.3	14.3	15.2	14.3	13.4	12.6	11.8	11.0	15.2	14.3
	°C	350	350	372	350	329	310	290	271	372	350
	°K	623	623	645	623	602	583	563	544	645	623
T_C	mv	2-448	2-448	2-518	2-448	2-400	2-320	2-254	2-194	2-518	2-448
	°C	724	724	759	724	700	660	627	597	759	724
	°K	997	997	1032	997	973	933	900	870	1032	997
T_C base inner	mv	24.6	25.4	27.2	25.8	25.0	23.7	22.9	22.1	27.5	26.0
	°C	593	612	654	621	602	572	553	534	661	626
T_C base outer	mv	24.1	25.4	27.0	25.6	24.6	23.4	22.9	22.1	27.2	26.0
	°C	581	612	649	616	593	564	553	534	654	626
$T_{Radiator}$	mv	21.4	22.0	23.3	22.3	21.7	20.8	20.3	19.7	23.4	22.6
	°C	518	532	562	562	525	504	492	478	564	546
V_{eb}, volts		985	990	992	992	992	994	999	1002	996	996
I_{eb}, mA		297	255	212	214	209	191	159	146	178	176
$E_{Filament}$, volts		5.1	5	4.8	4.8	4.8	4.8	4.6	4.6	4.6	4.6
$I_{Filament}$, amps		20.5	20	19.5	19.5	19.5	19.5	19	19	19	19
$I_{Coll.Heater}$, amps		0	7	11	11	11	7	7	7	13	12
$I_{Res.Heater}$, amps		~3	~3	~3	~3	~3	~2	~2	~2	~3	~3
Vacuum, 10^{-6} mm Hg		5.8	5.6	5	5	4.8	4.8	4.8	4.8	4.4	4.4
Measured Efficiency, %											

NOTES:

THERMO ELECTRON
ENGINEERING CORPORATION

Converter No. T 202 Des II Run No. 3 4 & 5 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-23-66	—	—	—	—	—	3-24-66	—	—	—
Time		1500	1510	1520	1530	1558	1630	0940	1002	1015	1028
Elapsed Time, Hours		—	—	—	—	—	—	—	—	—	—
T_O, °C		1518	1518	1517	1516	1711	1711	1710	1710	1710	1710
T_O Corrected, °C		1526	1526	1525	1524	1721	1721	1720	1720	1720	1720
$\Delta T_{Bell\ Jar}$, °C		9	9	9	9	13	13	13	13	13	13
T_H, °C		1535	1535	1534	1533	1734	1734	1733	1733	1733	1733
ΔT_E, °C		9	9	7	6	9	9	5	5	5	5
T_E, °K		1799	1799	1800	1800	1998	1998	2001	2001	2001	2001
V_O, volts		—	—	—	—	—	—	2.09	2.07	2.04	2.02
I_O, amps		22	23	12	6	23	22	0	0	0	0
P_O, watts		—	—	—	—	—	—	0	0	0	0
I-V Trace No.		20	21	22	23	24	25	—	—	—	—
T_R	mv	13.4	12.6	11.8	11.0	16.7	16.7	17.0	16.0	15.0	14.0
	°C	329	309	290	271	407	407	414	391	367	343
	°K	602	582	563	544	680	680	687	664	640	616
T_C	mv	2-400	2-320	2-254	2-194	2-538	2-376	2-254	2-254	2-254	2-254
	°C	700	660	627	597	769	688	627	627	627	627
	°K	973	933	900	870	1042	961	900	900	900	900
T_C base inner	mv	25.2	23.7	23.0	22.6	27.0	23.6	22.9	22.9	22.9	23.1
	°C	607	572	555	546	649	569	553	553	553	558
T_C base outer	mv	25.0	23.5	23.1	22.5	26.6	23.1	22.6	22.6	22.5	22.9
	°C	602	567	558	543	640	558	546	546	543	553
$T_{Radiator}$	mv	21.9	20.8	20.3	20.0	23.0	20.7	20.3	20.2	20.3	20.4
	°C	529	504	492	485	555	501	492	489	492	494
V_{eb}, volts		997	999	1002	1006	988	988	998	998	998	999
I_{eb}, mA		176	167	139	120	250	250	189	187	183	179
$E_{Filament}$, volts		4.8	4.8	4.6	4.6	4.9	4.9	4.6	4.6	4.6	4.6
$I_{Filament}$, amps		19	19	18.5	18.5	20	20	19	19	19	19
$I_{Coll.\ Heater}$, amps		11	9	11	10	9	~2	6	6	6	6
$I_{Res.\ Heater}$, amps		~2	~2	~2	~1	4	5.5	2	2	2	2
Vacuum, 10^{-6} mm Hg		4.3	4.3	4.3	4.3	4.3	4.3	3.6	3.6	3.6	3.6
Measured Efficiency, %											

NOTES:

THERMO ELECTRON
ENGINEERING CORPORATION

Converter No. T 202 Des II Run No. 5 & 6 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-24-66	—	—	—	0925	0935	0945	0955	1005	1020
Time		1042	1055	1115	1137	3-25-66	↓	↓	↓	↓	↓
Elapsed Time, Hours		—	—	—	—	—	—	—	—	—	—
T_0, °C		1710	1710	1710	1710	1580	1580	1580	1580	1580	1676
T_0 Corrected, °C		1720	1720	1720	1720	1589	1589	1589	1589	1589	1686
$\Delta T_{Bell\ Jar}$, °C		13	13	13	13	11	11	11	11	11	13
T_H, °C		1733	1733	1733	1733	1600	1600	1600	1600	1600	1699
ΔT_E, °C		5	5	5	5	12	6	6	6	5	15
T_E, °K		2001	2001	2001	2001	1861	1867	1867	1867	1868	1957
V_0, volts		2.02	1.97	1.95	1.95	.60	.80	1.00	1.20	1.40	.60
I_0, amps		0	0	0	0	41.7	8.5	6.9	4.9	2.5	60.0
P_0, watts		0	0	0	0	25.0	6.8	6.9	5.9	3.5	36.0
I-V Trace No.		—	—	—	—	—	—	—	—	—	—
T_R	mv	13.0	12.0	11.0	10.5	13.9	12.3	12.2	11.8	11.6	14.7
	°C	319	295	271	258	341	302	300	290	285	360
	°K	592	568	544	531	614	575	573	563	558	633
T_C	mv	2-254	2-254	2-254	2-254	2-379	2-060	2-014	1-986	1-956	2-606
	°C	627	627	627	627	627	530	507	493	478	803
	°K	900	900	900	900	900	803	780	766	751	1076
T_C base inner	mv	23.0	23.4	23.4	23.4	23.5	19.1	18.6	18.0	17.4	26.5
	°C	555	564	564	564	567	464	452	438	424	637
T_C base outer	mv	23.0	23.5	23.4	23.2	23.0	19.0	18.3	17.7	17.2	25.9
	°C	555	567	564	560	555	461	445	431	419	623
$T_{Radiator}$	mv	20.4	20.7	20.7	20.6	20.4	17.4	16.9	16.4	16.0	22.6
	°C	494	501	501	499	494	424	412	400	391	546
V_{eb}, volts		1000	1000	1001	1000	987	1000	1000	1003	1005	977
I_{eb}, mA		173	170	166	165	252	158	152	146	141	335
$E_{Filament}$, volts		4.6	4.6	4.6	4.6	5.0	4.6	4.6	4.6	4.6	5.2
$I_{Filament}$, amps		19	19	19	19	20	18	18	19	19	20.5
$I_{Coll.\ Heater}$, amps		7	10	9	9	0	0	0	0	0	0
$I_{Res.\ Heater}$, amps		4	3	1	0	3	4	4	3	3	4
Vacuum, 10^{-6} mm Hg		3.6	3.6	3.6	3.6	3.2	3.2	3.2	3.2	3.2	3.2
Measured Efficiency, %											

NOTES:

THERMO ELECTRON ENGINEERING CORPORATION

Converter No. T 202 Des II Run No. 6 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-25-66	—	—	—	—	—	—	—	—	
Time		1030	1040	1050	1100	1120	1130	1140	1150	1200	
Elapsed Time, Hours		—	—	—	—	—	—	—	—	—	
T_O, °C		1678	1676	1676	1676	1772	1772	1772	1770	1774	
T_O Corrected, °C		1688	1686	1686	1686	1783	1783	1783	1781	1785	
$\Delta T_{Bell\ Jar}$, °C		13	13	13	13	15	15	15	15	15	
T_H, °C		1701	1699	1699	1699	1798	1798	1798	1796	1800	
ΔT_E, °C		11	7	6	6	17	14	10	7	7	
T_E, °K		1963	1965	1965	1965	2054	2057	2061	2062	2066	
V_0, volts		.80	1.00	1.20	1.40	.60	.80	1.00	1.20	1.40	
I_0, amps		33.6	12.3	8.8	5.3	72.1	52.2	30.2	15.0	10.9	
P_0, watts		26.9	12.3	10.6	7.4	43.2	41.8	30.2	18.0	15.3	
I-V Trace No.		—	—	—	—	—	—	—	—	—	
T_R	mv	13.5	13.0	12.6	12.1	15.2	14.7	13.9	13.4	13.1	
	°C	331	319	309	293	372	360	341	329	321	
	°K	604	592	582	566	645	633	614	602	594	
T_C	mv	2-364	2-158	2-108	2-054	2-778	2-600	2-396	2-253	2-202	
	°C	682	579	554	527	889	800	698	627	601	
	°K	955	852	827	800	1162	1073	971	896	874	
T_C base inner	mv	23.4	20.5	19.9	19.1	28.7	26.5	23.9	21.9	21.1	
	°C	564	497	483	464	690	637	576	529	511	
T_C base outer	mv	22.9	20.2	19.5	18.9	27.9	25.9	23.2	21.4	20.7	
	°C	553	489	473	459	671	623	560	518	501	
$T_{Radiator}$	mv	20.4	18.4	17.9	17.2	24.0	22.6	20.8	19.3	18.9	
	°C	494	447	436	419	579	546	504	468	459	
V_{eb}, volts		985	993	995	999	968	974	982	988	989	
I_{eb}, mA		266	203	191	173	411	360	293	248	234	
$E_{Filament}$, volts		5.0	4.8	4.8	4.6	5.4	5.2	5.0	4.8	4.8	
$I_{Filament}$, amps		20	19	19	19	21.5	21	20	19.5	19.5	
$I_{Coll.\ Heater}$, amps		0	0	0	0	0	0	0	0	0	
$I_{Res.\ Heater}$, amps		4	3	3	3	3	3	3	3	3	
Vacuum, 10^{-6} mm Hg		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	
Measured Efficiency, %											

NOTES:

THERMO ELECTRON
ENGINEERING CORPORATION

Sheet 7 of 7

Converter No. T-202 Run No. 7 Observer B. Gunther

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date		3-28-66	—	—	—	—	—				
Time		1045	1105	1120	1300	1313	1327				
Elapsed Time, Hours		—	—	—	—	—	198.3				
T_O, °C		1682	1700	—	—	—	—				
T_O Corrected, °C		1692	1710	—	—	—	—				
$\Delta T_{Bell\ Jar}$, °C		13	13	—	—	—	—				
T_H, °C		1705	1723	—	—	—	—				
ΔT_E, °C		7	5	—	—	—	—				
T_E, °K		1971	1991	—	—	—	—				
V_O, volts		1.00	2.25	—	—	—	—				
I_O, amps		9.4	0	—	—	—	—				
P_O, watts		9.4	0	—	—	—	—				
I-V Trace No.											
T_R	mv	14.9	15.2	15.9	16.0	15.6	15.0				
	°C	364	372	388	391	381	367				
	°K	637	645	661	664	654	640				
T_C	mv	2-162	2-162	2-162	2-162	2-162	2-162				
	°C	581	581	581	581	581	581				
	°K	854	854	854	854	854	854				
T_C base inner	mv	20.8	21.3	21.4	20.9	20.9	20.9				
	°C	504	516	518	506	506	506				
T_C base outer	mv	20.4	21.0	21.1	20.6	20.6	20.5				
	°C	494	508	511	499	499	497				
$T_{Radiator}$	mv	18.6	19.1	19.2	18.8	18.8	18.7				
	°C	452	464	466	457	457	454				
V_{eb}, volts		991	999	—	—	—	—				
I_{eb}, mA		205	182	—	—	—	—				
$E_{Filament}$, volts		4.8	4.6	—	—	—	—				
$I_{Filament}$, amps		19	19	—	—	—	—				
$I_{Coll.Heater}$, amps		0	5	.5	4	4	4				
$I_{Res.Heater}$, amps		0	0	.585V 1.5A	.780V 2.0A	.587V 1.5A	0				
Vacuum, 10^{-6} mm Hg		3.4	3.4	3.4	3.4	3.4	3.4				
Measured Efficiency, %											

NOTES: No cooling strap on reservoir during run 7. Data points 4, 5 & 6 give T_R v.s. heater power at constant T_C base inner.